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THE WESTPAC BROADCAST REALIGNMENT— EVOLUTION AND CONCEPT

William C. Hardy

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THE WESTPAC BROADCAST REALIGNMENT— History, EVOLUTION AND CONCEPT

(10) William C. Hardy

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2. Enclosure (1), one of a series of OEG communications studies, reports the results of the analysis of the impact of the OEG-recommended realignment of the WESTPAC broadcast. Each step in the realignment is analyzed to show its effect on service activity, broadcast workloads, and distribution of traffic among the various channels. The concepts and evolution of the realignment are also discussed.

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THE WESTPAC BROADCAST REALIGNMENT - HISTORY, EVOLUTION, AND CONCEPT

December 1971

William C. Hardy

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GLOSSARY OF TERMS AND ABBREVIATIONS

BKS – (broadcast keying station) – the area communications station responsible for composing and keying the broadcast.

Channel – one of the possibly many portions of a signal that carries information.

First-run message – numbered message appearing on the broadcast for the first time; other messages include reruns and unnumbered messages.

Frequency diversity – practice of copying 2 frequencies carrying the same signal simultaneously to enhance reception.

Full-period termination – shore-to-ship communications link between one unit and the communication station maintained continuously for delivering and receiving messages.

Garbled message – message received with too many errors to be intelligible in its entirety.

Guard (for a channel) – the responsibility to continuously copy that channel.

Heading of a message – that part of a message showing its originators, routing indicators, and to whom it is addressed for information and action.

Heading recaps – reruns of headings from messages or messages showing to whom each broadcast message was addressed.

Major combatant – collective description for carriers and cruisers.

MAPU – (multiple address processing unit) – an electrical message routing device that reproduces message tapes at remote terminals according to the message routing indicators; produces a tape for each indicator for a local destination.

Message number – designator appended to a message when it is broadcast showing the channel, month, and its position in the month's first-run traffic. The message number serves as a unique reference for all first-run messages.

Outage – period during which no usable traffic is received because of power failure, equipment failure, or complete loss of signal.

Pigeon post – delivery of messages to carriers via airplanes and thence to other units via helicopter.

Routing indicator – 7-letter code indicating the area destination of a message and channel on which it should be transmitted.

Simulkeying – practice of transmitting the same information on different broadcast channels or on different broadcasts.

SRR – Service Request Rate (see equation (1)).

STROFAC – stabilized routing for afloat command; a routing doctrine under which the routing indicator for full-period terminations remains the same, regardless of the communications station maintaining the termination.

Subscriber – unit guarding a broadcast or broadcast channel.

UCC-1 – unit that demodulates the multichannel broadcast.

Voluntary rerun – see ZFG.

ZAT – message originated by the communications station acknowledging receipt of a service request and indicating which of the requested numbers were of concern.

ZDK – message retransmitted because it was requested for rerun by one of the units to which it was addressed.

ZFG – message retransmitted by the communications station without there having been a service request for it.

INTRODUCTION

From 1965 to 1967, fleet broadcasts serving the Western Pacific (WestPac) experienced a rapid, unanticipated growth in traffic volumes as a result of the increased tempo of operations in the South China Sea. Large investments in equipment and personnel, and major procedural changes, such as the de-netting of the broadcasts keyed from Guam and Japan and transfer of the broadcast keying responsibilities from NCS Guam to NCS Philippines, eventually enabled WestPac communications stations to handle the demand without resorting to "pigeon post" and other nonelectrical means of delivery. Despite these measures, when traffic volumes stabilized in mid-1967, the load still could not be handled without frequent backlogs.

One factor recognized as degrading the WestPac broadcast capabilities was the inordinate number of service requests (requests for retransmission of messages missed on the first run). Late in 1967 and early in 1968, such requests were being received in numbers approximating 50 percent of the first-run volume, with the number of service requests for messages appearing on some channels running as high as 110 percent of the first-run volume. The rebroadcasting of these messages was consuming about 10 percent of the total broadcast capacity, or about 2 hours of broadcast time each day. Because all these requests had to be screened and processed, replies to service requests were being delayed as much as 36 hours.

In response to this situation, the Operations Evaluation Group (OEG) of the Center for Naval Analyses was requested to analyze the WestPac broadcast to isolate the causes for the high service request rate and to determine what could be done to improve the situation within the constraints of the existing system. This study was begun in April 1968, according to the plan set forth with the collection of data on the existing broadcast.

Subsequent analyses of this data, which are discussed in detail, supported two major recommendations for reducing the number of service requests.

- "Realign the guard lists for broadcast channels to conform with the operational organization."
- "Improve the management of voluntary reruns to increase their effectiveness in reducing service requests."

These rather general recommendations were later made specific in which it was shown that both objectives could be met by functionally realigning the multichannel broadcast in the manner illustrated in table 1.

This realignment was eventually effected in three stages (see table 2): by implementing automatic reruns on 14 September 1969; by removing major combatants as subscribers to channels 1-4 in February 1970; and by realigning the broadcast subscribership on 18 August 1970. For ease of reference, these realignment steps are designated as Phases I, II, and III, respectively, in what follows.

TABLE 1

PROPOSED REALIGNMENT OF THE WESTPAC MULTICHANNEL BROADCAST

Channel	Function before realignment	Function after realignment
PASW	Rebroadcast of traffic from other channels; recaps and ZDK's for units on Yankee Station.	Primary traffic channel for destroyers and DLG's.
PSPC	Full-period termination overload channel as needed; automatic rebroadcast of PUSN numbers transmitted during evening transition period.	Automatic 2-hour lagged rebroadcast of PASW traffic; overload channel for destroyers and DLG's, as necessary.
PALD/RTT	Primary broadcast traffic channel for all WestPac units; simulkeyed with the single channel broadcast for units not MUX equipped.	Primary traffic channel for amphibious, auxiliary, minesweeper units; simulkeyed with PRTT.
PUSN	Overload channel for PALD.	Automatic 2-hour lagged rebroadcast of PALD traffic; overload and NoForn channel for amphibious, auxiliary, minesweeper units, as necessary.
PNSC	Special broadcast for major warships cleared to carry Top Secret messages.	Primary traffic channel for major warships.
POPI	Special intelligence broadcast.	No change.
PHIC	Overload channel for PNSC.	Automatic 2-hour lagged rebroadcast of PNSC traffic; overload channel for PNSC or POPI, as required.

TABLE 2

THREE-PHASE IMPLEMENTATION OF THE WESTPAC BROADCAST REALIGNMENT

Channel	Original function	Phase I 15 Sep 1969	Phase II Feb 1970	Phase III 18 Aug 1970
PASW	ZFG's, ZDK's, Recaps	Automatic rebroadcast of PALD traffic	Major warships deleted as subscribers	Primary traffic channel for destroyers, DLG's only
PSPC	Termination overload	Automatic rebroadcast of PUSN traffic	Major warships deleted as subscribers	Automatic rebroadcast of PASW traffic
PALD/RTT	Primary traffic channel; all subscribers	No change	Major warships deleted as subscribers	Primary traffic channel for amphibious, auxiliary, and mine units
PUSN	PALD overload	No change	Major warships deleted as subscribers	Automatic rebroadcast of PUSN traffic
PNSC	Top Secret broadcast for major warships	No change	Primary traffic channel for major warships	No change
PHIC	Overload for PNSC	Automatic rebroadcast of PNSC traffic	No change	No change

This study describes the effect of each of these changes to illustrate improvements that could result from adoption of this realignment in other areas. The results generally show that judicious management of multichannel broadcast capacity can simultaneously increase capabilities, reduce service requests, and reduce the communications workload, both at the communications station and aboard the subscribing units.

MAJOR RESULTS AND CONCLUSIONS

The WestPac broadcast realignment produced the following beneficial effects.

The average number of service requests received per 1000 first-run messages was reduced from 1097 to 333, or approximately 70 percent. This means that the number of service requests handled by communications stations during a typical broadcast day was reduced from 1440 to 400.

The overall reduction in the number of service requests was produced by two different effects:

- The automatic rebroadcasts initiated in Phase I reduced the service request rate about 50 percent. The service request rate (SSR) is defined as the ratio

$$\frac{\text{number of service requests}}{(\text{number first-run messages})\ (\text{number of subscribers})}\ . \tag{1}$$

It is an estimate of the average probability that a given subscriber will request service on a given message. The decrease in this measure is an indication of the proportion of all messages missed on first transmission that were picked up from the automatic rebroadcasts after they became available. However, since the automatic rebroadcasts could not be copied by all mux-equipped units during Phases I and II, the proportion of missed messages obtained from the rebroadcasts by those units that could copy them was probably substantially greater than the 50 percent shown here.

- The subscribership realignments effected in Phases II and III reduced the number of subscribers to 2 of the 3 primary traffic channels by more than 50 percent, thereby reducing the number of chances for service requests to be generated. Since the number of chances for a service request on a message broadcast on a given channel varies directly with the number of subscribers copying that channel, the total number of service requests can be reduced without reducing the service request rate by reducing the number of subscribers. This is precisely what happened with the Phase II realignment. There was no reduction in the overall service request rate. However, by removing major combatants as subscribers to PALD/RTT and PUSN, the realignment reduced the number of service requests per 1000 first-run messages from 628 to 559. Similarly, while the Phase III realignment did reduce the service request rate somewhat by making automatic rebroadcasts accessible to more subscribers, the more significant effect of this step was to reduce by half the number of subscribers to PALD/RTT and PUSN.

The realignment substantially reduced the workload for the communications station, in that:

- As indicated above, the ZDK screening and processing loads were reduced 70 percent.
- The subscribership realignment enabled automatic segregation and routing of broadcast traffic to the appropriate channel(s). The ship type/primary broadcast traffic channel correspondence established by the completed realignment (as shown in table 1) enabled the promulgation of worldwide broadcast routing indicators that indicated the primary traffic channel guarded by the intended recipient. By programming MAP (Multiple Address Processor) units to recognize these and route the message automatically to the appropriate channel(s), the WestPac BCA was eventually able to eliminate time- and personnel-consuming manual routing procedures.

The broadcast workload for the individual WestPac subscribers was substantially reduced. As indicated above and illustrated in table 2, realignment of subscribership in Phase II reduced the number of primary traffic channels copied by major combatants from 3 to one, while the realignment in Phase III reduced the number of primary traffic channels copied by the majority of the other mux-equipped subscribers from 2 to one. The effects of this are illustrated by the following.

Of 1000 first-run broadcast messages:

- Major warships copied 1000 before the realignment, but only 140 after.
- Destroyers and most DLG's copied 806 before the realignment, but only 371 after.
- The majority of auxiliary and amphibious units copied 806 before the realignment, but only 488 after.

The excerpts from messages contained in appendix A cite examples of the direct payoffs from these reductions in traffic volumes, such as:

- Changes to three- instead of two-section communications watches.
- Reduction of psychological fatigue of watch standers.
- Significant reduction in the consumption of teletype paper and similar consumables (estimated in some instances to be as great as 30 percent).
- Greater equipment reliability because of the opportunities to take equipment off line and perform preventive maintenance.
- Reduction of file sizes, thereby reducing the congestion in shipboard communications spaces.

BACKGROUND

THE FLEET BROADCAST

The fleet broadcast is a one-way shore-to-ship communications link maintained at all times as the primary means of delivery to afloat units of messages originated by shore commands or by other afloat units beyond the range of ship-to-ship communications paths. To provide worldwide coverage, the ocean areas of the world are divided into 8 communications regions. Within each region there is a broadcast keying station (BKS), which composes the regional broadcast, and a number of other stations to which the broadcast keystream is relayed for transmission. Each of these stations transmits the keystream on as many as 20 HF (high frequency) and LF (low frequency) carriers to provide diversity coverage of the communications region, so that each broadcast subscriber (unit copying the broadcast) can select one or two RF (radio frequency) paths that propagate well into its immediate area.

THE SERVICE MECHANISM

Since all units operating within a given communications region are required to guard the appropriate broadcast, each unit must copy all messages and select from those received the ones addressed to it or of interest to it. Even though frequency and equipment redundancy is provided, local deterioration of the RF paths being used and occasional power or equipment outages make it impossible for every subscriber to receive every message in an intelligible form. Consequently, some mechanism is required to provide for retransmission of those messages not received on the first run. The procedures that have evolved to satisfy this requirement can be described briefly as follows:

- When a message is transmitted, it is assigned a channel sequence number. These numbers run in sequence throughout the month, so a subscriber can tell at a glance whether a sequence is complete.
- Each broadcast subscriber is required to maintain a complete broadcast file, consisting of a copy of each numbered message or verification that a missing message was not of concern to that unit. When a break in the sequence of a subscriber's broadcast file occurs or when a message is received but, because of garbles, is unintelligible and it cannot be verified as being meant for that unit, the unit is alerted to the fact that another copy of the message originally broadcast under that sequence number may be required.
- When this occurs, the unit has three alternatives:
  - It may wait for a rebroadcast. To enhance delivery probabilities, the BKS may rebroadcast messages (ZFG's) or broadcast the headings of messages (recaps) whenever there are no new messages to be transmitted. Receipt of one of these may complete the unit's file without any other action on its part.
  - It may obtain, from other units via local intership circuits, a copy of the message or verification that it was not of concern.
  - The unit may request retransmission of the message by the BKS.

Retransmission requests are called service requests. When a service request on a message is received, the BKS first screens it (checks it against the station files) to determine whether it was addressed to the unit requesting it. If it was not, the station originates a message informing the unit of that fact and no further action is necessary. If it was addressed to the unit requesting it, the BKS must retrieve or manufacture a tape for the message and retransmit it as a ZDK (request rerun). This is done usually on the broadcast, but sometimes on a full period termination (if the requesting unit has one) or other circuits, such as the primary ship-shore circuit. The feedback system produced by the service mechanism is shown in figure 1.

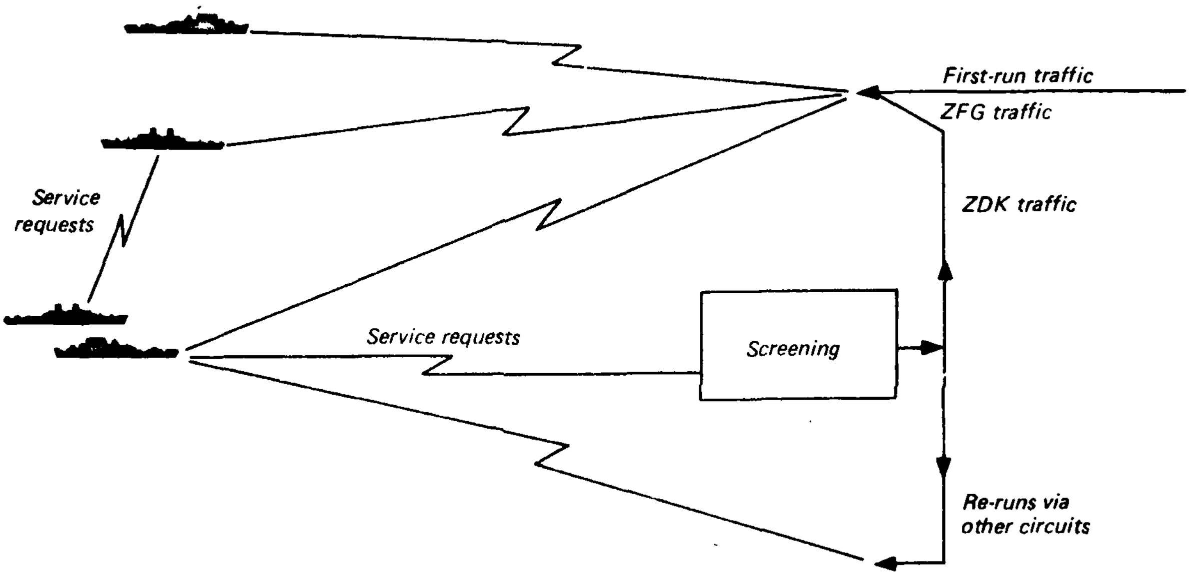

FIG. 1: TRAFFIC FLOW ON THE FLEET BROADCAST

It should be clear from this description that the number of service requests received by the BKS can be a major factor affecting performance. If traffic volumes are already high, the additional demand created by replies to service requests can cause or contribute to backlogs. In addition, the manpower required to screen service requests and prepare ZDK's may overburden the BKS broadcast resources and necessitate longer watch sections.

These were the problems that stimulated the study. To appreciate their solution, it is first necessary to examine more closely the structure of the fleet broadcast as it had evolved at the time the study was initiated.

EVOLUTION OF THE MULTICHANNEL BROADCAST

The present fleet broadcast system is an on-line encrypted, 100 word-per-minute teletype system keyed in two modes. One is the older, so-called single channel FSK (frequency shift keying) mode that provides for one or 2 traffic channels per RF carrier. The other mode is a newer, multichannel system, in which as many as sixteen 100 word-per-minute teletype channels can be multiplexed on a single carrier frequency, thereby greatly increasing the traffic capacity of each frequency allotted to the broadcast.

To enhance reliability, the general practice in using the multichannel system is to key the same messages on 2 channels -- one in the upper sideband and one in the lower to enable inband diversity reception of 8 traffic channels. When the multichannel system was introduced, these 8 channels were functionally designated as shown in table 3, with the idea that traffic would eventually be routed to the various channels on the basis of message content or purpose.

TABLE 3

FUNCTION DESIGNATIONS FOR THE MULTICHANNEL BROADCAST

Channel	Abbreviation	Designation
1	–ASW	Antisubmarine warfare
2	–SPC	Special circuit
3	–ALD	Allied broadcast
4	–USN	U.S. Navy-only broadcast
5	–NSC	Nuclear strike coordination
6	–OPI	Operational intelligence
7	–HIC	High command
8	–MET	Meteorological

With the exception of channels 6 and 8, however, these dedicated functional uses were never realized. Since prohibitive costs and space limitations prevented installation of the full 8-channel receiver system in all units, the receiver capabilities installed varied from unit to unit as shown in table 4. Consequently, the procedures for routing traffic to the various channels that developed in most broadcast areas were to:

- Require all units to copy every broadcast channel they were equipped to copy.
- Route as much general traffic as possible to channels 3 and 4.
- Route to channel 5 all traffic of interest only to major combatants (carriers and cruisers) or to other units with embarked commands (usually DLG's, LPH's, or large service force units).

- Route the special interest broadcast traffic to channels 6 and 8 as intended.
- Leave the other channels on stand-by, running test messages or nonessential traffic such as heading recaps or ZFG's (voluntary reruns), and use these for first-run traffic only as necessary by routing overloads on channels 5 to 7 and selectively routing messages from backlogs on channels 3 and 4 to channel 2.

TABLE 4

BROADCAST RECEIVE CAPABILITIES OF SMALLER WESTPAC AREA UNITS
(Number of ships as of 17 Jul 69–30 Aug 70)

Ship types	Single channel	Channels 3 and 4 only	Channels 1-4	All
Destroyers/DLG's	7/7	9/0	39/53	3/3
Servforce units	19/10	14/10	4/7	2/0
Phibforce units	5/2	9/1	8/9	–/–
Minetorce units	4/0	7/9	–/–	–/–

Note: Carriers and cruisers are usually equipped to copy all channels of the multichannel broadcast.

While these procedures minimize the amount of traffic segregation required to ensure that messages for a unit are broadcast on a channel that it does copy, they do not make efficient use of the existing capability. Channels 1, 2, and 7 are used only when backlogs develop and their use in this circumstance requires traffic segregation. Moreover, these procedures have some undesirable features:

Multichannel broadcast subscribers must guard more channels than is really necessary. The requirement for all units to guard all channels they are equipped to copy is undesirable from the subscriber viewpoint, because it increases the communications workload and the amount of equipment that must be operated and maintained to copy the broadcast. Moreover, it represents an inefficient use of capacity when all unit's messages are broadcast on several channels, the probability that a message will be of interest to a given subscriber decreases. Thus, more time is spent screening traffic, and more paper, tape, and manpower are expended per message of interest to the receiving unit. This requirement is also undesirable from the communications station's viewpoint, because it increases the service requests in two ways. First, since there are more subscribers to each channel, there is a greater chance that at least one unit will miss a message broadcast on a channel. Second, the average number of messages missed by each subscriber is greater, because the number of messages missed during an outage affecting all channels (such as a power outage or a UCC-1 failure) is greater.

Routing of most traffic to 2 channels produces an unbalanced demand that increases the likelihood that backlogs will develop. The routing doctrine described above makes channels 3

and 4 the ones to which most traffic is routed, with channel 5 as an alternate for special kinds of traffic. Consequently, the first-run demand on these 2 channels is usually higher than necessary, while channel 5 tends to be underutilized.

Management of voluntary reruns becomes haphazard, with resulting degradation of their effectiveness in reducing the number of service requests. Because the bulk of the first-run traffic is routed to channels 3 and 4, there are few opportunities to run ZFG traffic on them. Moreover, such opportunities appear sporadically during the day. Unless ZFG's appear in a timely fashion with some regularity, as was observed, their effectiveness in reducing the number of service requests is greatly reduced, because operators are reluctant to wait for a ZFG or recap without reasonable assurance that one will appear. Moreover, since many subscribers cannot copy the other broadcast channels (see table 4), a well-regulated schedule of ZFG's that might appear on channels 1 and 2 (under the procedures described above) is not accessible to many units.

THE REALIGNMENT AND ITS IMPLEMENTATION

The problems created by the procedures for routing traffic through the multichannel broadcast discussed above generally suggest that when the broadcast capacity is used this way in an area where traffic volumes are high, individual subscribers will be overburdened and the BKS may be faced with inordinate numbers of service requests. These were the problems being encountered in WestPac when the study was initiated. In retrospect, it becomes apparent that the routing procedures were indeed contributing greatly to the problems.

While that study exposed these effects in a way that showed that more efficient traffic routing could alleviate the service problem it was not until June 1968 that a feasibility study indicated that routing traffic to the multichannel broadcast on the basis of ship type was the way to go. This concept was implemented gradually from September 1969 to August 1970 in three phases, as indicated in the introduction and tables 1 and 2. While this gradual approach to the realignment was motivated in part by a desire to avoid hasty actions and the consequences that would arise if any of the study suppositions were in error, the phases were also timed to take advantage of other changes occurring in the WestPac communications area. These changes are described below to show that other efforts contributed greatly to the success of the broadcast realignment.

Simulkeying of the Single and Multichannel Broadcasts

In June 1969, before Phase I of the realignment, the decision was made to increase the commonality of the WestPac broadcast by simulkeying the single-channel broadcast with channel 3 of the multichannel broadcast. This was implemented in July 1969 and was shown to have reduced the combined service request rate on these channels by making it easier for units copying the broadcasts in these different modes to obtain missing messages from ships in company. Thus, when Phase I of the broadcast realignment was implemented, the benefits realized from the automatic reruns were probably greater than they would have been earlier, because the single channel subscribers benefited indirectly from the automatic reruns.

Stabilized Routing for Afloat Commands (STROFAC)

Phase II of the realignment was deferred until the STROFAC concept was implemented in WestPac. This routing concept calls for the assignment of a permanent routing indicator for the full-period terminations maintained by units with embarked commands. Under the older procedure, the routing indicator was changed each time the termination was shifted from one communications station to another.

The direct impact of STROFAC was to enable automatic rerouting of traffic by changing the destination of the STROFAC routing indicator, thereby avoiding delays that used to be generated when message originators not yet informed of a shift in termination misrouted messages for embarked commands by using the old routing indicator. The indirect effect of STROFAC contributing to the success of Phase II was to make the STROFAC routing indicator rather than the broadcast routing indicator the one preferred for routing messages. This, in turn, had the effect of diverting much of the traffic for units with embarked commands from the broadcast to their full-period terminations, thereby decreasing the amount of traffic that was routed to channel 5 after the Phase II realignment.

To see how STROFAC aided the realignment, it was estimated that channel 5 would be required to carry 41 percent of the total first-run traffic (112 percent of its capacity) after major combatants were deleted as subscribers to channels 1-4 and all their traffic routed to channels 5 and 7. In fact, when Phase II was implemented after STROFAC, channel 5 carried only 24 percent of the total traffic. The backlogs on channel 5 that might have necessitated frequent activation of channel 7 for first-run traffic never materialized.

Modifications of the Worldwide Routing Indicators

Before Phase III of the realignment was implemented, the worldwide routing indicators for the WestPac broadcast were modified to conform to the realignment. To do this, the older single-broadcast routing indicator, RHMPSII (when NCS Philippines was BKS), was replaced with the set of 8 routing indicators shown in table 5.

TABLE 5

WESTPAC BROADCAST ROUTING INDICATORS PROMULGATED ON 1 AUGUST 1970

Characters 1-4 BKS derivative	Character 5 capabilities	Characters 6 and 7 ship type
(RHMP denotes NCS Philippines; RUHG denotes NCS Guam)	T – single channel only K – channels 3 and 4 only I – channels 1-4 only X – all channels, except possibly 6 and 8	AA – DLG, DD, DE, etc. BB – all other units except those with full-period terminations

Example: Routing indicator for an amphibious unit capable of copying channels 3 and 4 only would be RHMPKBB.

This change in routing indicators served the twofold purpose of identifying each unit's broadcast receive capabilities and of designating the channel to which the message should be routed. It facilitated the BKS manual segregation of traffic and eventually enabled automatic routing of traffic to the appropriate channel. At the same time, the broadcast routing indicator for units with STROFAC routing indicators was deleted from the Worldwide Routing Guide, so that even more broadcast traffic was diverted to the full-period terminations.

ANALYSES

DATA AND APPROACH

The following analyses of the effects of each phase of the realignment are based largely on information contained in the daily WestPac TacCom (tactical communications) reports. While this data is not as fine as would have been available had special data collection efforts been undertaken, greater effort in documenting the realignment effects did not seem warranted. Gross improvements in performance and the absence of problems generally revealed sufficiently the efficacy of each realignment step as it was taken.

The approach taken in these analyses is to make a before-and-after comparison of the broadcast performance over relatively short periods to minimize the possibility of the data's being influenced by other factors, such as significant changes in first-run traffic loads or the number of broadcast subscribers. During each of these periods, the data is examined to show how much each realignment step contributed to the primary objective of reducing service requests. In addition, the changes in routing procedures introduced before and during Phases II and III of the realignment were expected to produce other effects, such as:

- Changes in the distribution of traffic among the various channels and between the broadcast and the full-period terminations.
- Reductions in the number of channels guarded by broadcast subscribers with a consequent reduction in the amount of traffic copied each day.
- On the negative side, an increase in total first-run traffic handled caused by the necessity of transmitting some messages on more than one channel of the broadcast to effect delivery.

Where applicable, the magnitudes of these effects are estimated and analyzed. However, since the rather general data available in the daily TacCom reports does not directly reflect such effects, their analysis must be considered to be less precise than the analysis of the effects of the realignment on service activity.

All of the pertinent data is summarized in appendix B. Portions of that appendix are modified and reproduced below as necessary to support the discussion.

REDUCTION OF SERVICE ACTIVITY

Service requests represent an additional burden to the communications system in three ways:

- Aboard ship, the preparation and transmission of request messages and the logging efforts required to keep track of which numbers are missing, when their retransmission was requested, and when the service replies were received adds to the workload.
- Since service requests must be screened at the communications station, and ZDK tapes and ZAT messages (replies to service requests indicating which messages are not of concern and which will be rerun) must be prepared, service requests add to the broadcast workload at the communications station.

• Because some proportion of the messages requested must be rerun on the broadcast, service requests reduce the broadcast capacity for first-run traffic and increase the likelihood that a channel will become backlogged.

The degrading effects suggest three measures of effectiveness to indicate the effects of the realignment on service requests.

1. <u>The Service Request Rate (SRR)</u>

The service request rate is a measure of the average probability that a given subscriber will request service on a given message. It is calculated for a given channel, i, as the ratio

$$SRR_i = \frac{R_i}{M_i \cdot S_i} \quad . \tag{2}$$

where

R_i = total number of service requests received for messages on channel i, counted so that, e.g., one message requested for retransmission by 5 different subscribers represents 5 requests;

M_i = total number of first-run messages on channel i; and

S_i = total number of subscribers to channel i.

The overall broadcast area service request rate is calculated by combining the channel values according to the formula

$$SRR(Area) = \frac{\sum_{i=1}^{\mu} R_i}{\sum_{i=1}^{\mu} M_i \cdot S_i} \quad , \tag{3}$$

where R_i, M_i, and S_i are defined as in (2), and μ = number of channels considered.

The service request rate, then, indicates the frequency with which subscribers originate service requests instead of using other means to obtain missing messages. While it may also indirectly reflect the frequency with which messages are missed on the broadcast, since the number of requests (R_i) will increase with the number of missing messages when all other factors are the same, the correlation between the nonreception rate and the SRR may not be the same from channel to channel (see, e.g., table XIII of reference (b)). Consequently, the reader is warned not to try to interpret the SRR as an indicator of relative fidelity of the various broadcast channels.

2. <u>Daily Number of Service Requests (DNSR)</u>

The DNSR is simply the numerator in equation (3). This count of the number of service requests is an indicator of the screening workload at the communications station created by

the service mechanism. It is important to distinguish this measure from the SRR; it is possible for the DNSR to drop as a result of a reduction in the number of subscribers to a channel, while the SRR remains constant. When this happens, the DNSR is an indicator of the effects of changes in traffic management procedures, as opposed to changes in the shipboard situation. Since the DNSR varies with the first-run volume, it will sometimes be convenient to also express this loading as a rate defined by

$$\text{DNSR}_i \text{ per 1000 first-run} = \frac{R_i}{M_i} \times 1000, \tag{4}$$

where R_i and M_i are defined as in (3).

3. Demand Represented by a First-Run Message

As indicated in the background discussion, the total demand on a broadcast channel is a combination of the first-run traffic and the ZDK's. By assigning each first-run message on a channel a value 1 + M, where

> M = the proportion of the first run messages appearing on the channel that must be rebroadcast as ZDK messages, (5)

this demand can be conveniently expressed as a measure that does not depend on the first-run traffic volume. In doing this, M represents the marginal increase in demand caused by the service mechanism and indicates the extent to which ZDK messages are reducing the capacity of the broadcast. Moreover, the values of 1 + M for different periods can be compared to determine the change in potential broadcast capacity produced by changes in service activity by the equation

$$\text{Percent change in capacity} = \frac{\text{(demand before)-(demand after)}}{\text{(demand after)}} \times 100. \tag{6}$$

While the denominator of equation (6) may appear to be in error, the derivation in appendix C shows that this is the proper measure.

Phase I: Implementation of Automatic Reruns

As indicated in table 2, the first step in the realignment was to activate the recommended schedule of automatic rebroadcasts of first-run traffic appearing on channels PALD/RTT, PUSN, and PNSC 2 hours later on channels PASW, PSPC, and PHIC, respectively. These procedures were initiated on 15 September 1969.

Unfortunately, the change occurred at the same time as the shift of BKS from NCS Philippines to NCS Guam, which confused the situation and created backlogs that sometimes prevented use of the designated channels for reruns. Consequently, data from the 2 weeks immediately following activation of the reruns was not considered to be a fair test. Collection of data to evaluate the effects of the reruns was thus deferred until 6 October, when BKS authority returned to NCS Philippines. Since this had the effect of separating the sample periods by 22 days, loading characteristics for the before-and-after periods were compared to

determine whether changes had occurred that might significantly affect the various measures examined. Table 6 shows that possible significant changes in loading on channels PALD/RTT and PNSC occurred during this period, so the basic data appearing in table A-1 (appendix A) was adjusted in this manner:

- Since the service request rate is already normalized by both the number of subscribers and the first-run volume, it was left unchanged.
- The daily number of service requests was adjusted by dividing the number shown in table A-1 by $(1 + x)(1 + y)$, where x = proportional change in the average number of subscribers and y = proportional change in the average number of first-run messages per day, as shown in table 6.
- The average number of requests per 1000 first-runs shown in table A-1 was divided by $(1 + x)$.

TABLE 6

CHANGES IN LOADING CHARACTERISTICS BETWEEN THE BEFORE-AND-AFTER SAMPLE PERIODS USED IN THE EVALUATION OF PHASE I

		Channel		
		PALD/RTT	PUSN	PNSC
Average number of subscribers	Before	65.2	50.2	14.0
	After	86.8	48.9	12.3
	Change	+24.9%	−2.6%	−12.1%
	Adj. factor (1 + x)	1.249	.984	.879
Average number of first-run messages per day	Before	511.8	438.9	229.9
	After	565.9	438.2	250.0
	Change	+9.6%	0	+8.0%
	Adj. factor (1 + y)	1.096	1.00	1.08

Table 7 shows the changes in service activity resulting from the automatic reruns. These changes were estimated on the basis of the adjustments described above, so that the values for the average number of requests per day and the average number of requests per 1000 first-runs shown for the period after activation of the reruns (6 October-1 November) reflect what would have happened had the loading conditions been the same as those during 1-14 September. These results support the following conclusions about the impact of the automatic reruns on service activity:

The automatic rebroadcasts reduced the overall service request rate by half. Observe from table 7 that the overall service request rate was reduced 50 percent. This means that about half of the missing messages on which a service request would have been originated were picked up from the automatic reruns. However, this general result should be considered in light of the following:

- During Phase I, the automatic reruns were not available to all units. In fact, of the 87 or so subscribers to PALD/RTT during this period, about 35 copied the single-channel broadcast and, consequently could only benefit indirectly from the reruns. Moreover, as table 7 illustrates, about 60 percent of the smaller multichannel subscribers were not equipped to copy the channels on which the reruns appeared. This suggests that the actual reduction in service request rate for units that could copy the rerun channels were probably considerably greater than the 47 and 58 percent shown in table 7 for channels PALD/RTT and PUSN, respectively.

- Automatic reruns can be expected to have a lesser visible effect on the service request rate for terminated units. Broadcast subscribers that also have full-period terminations are required to report their missing broadcast numbers every 4 hours in their COMSTAT (Communications Status Report); these reports are then treated as service requests by the communications station. Since the automatic reruns were lagged 2 hours, about half of their missing numbers would be expected to have shown up in the COMSTAT report, which is treated like a service request, whether they were subsequently picked up from the automatic reruns or not. This effect is illustrated in table 7 by the fact that the reduction in the service request rate for channel PNSC, most of whose subscribers have a full-period termination, was only about half that observed for other channels. Thus, the suggestion again, is that actual reduction in the service request rate was somewhat greater than the proportions shown in table 7.

TABLE 7

CHANGES IN SERVICE ACTIVITY RESULTING FROM AUTOMATIC RERUNS

		Channel			
		PALD/RTT	PUSN	PNSC	Overall
Service request rate (SRR)	Before	.019	.024	.037	.022
	After	.010	.010	.028	.011
	Reduction	47.4%	53.3%	24.3%	50.0%
Average number of requests per day	Before	644.9	531.1	118.9	1294.9
	After	396.2	251.9	100.3	748.4
	Reduction	38.6%	52.6%	15.6%	42.2%
Average number of requests per 1000 first-run	Before	1260.2	1210.1	517.4	1096.9
	After	682.0	511.1	385.1	545.2
	Reduction	45.9%	57.8%	25.2%	50.3%

(U) *The average number of service requests received by area communications stations was reduced 40-50 percent.* This result is clearly illustrated in table 7 by the figures for the average number of requests per 1000 first-run messages. This shows that the screening workload at the communications stations was substantially reduced in return for the extra effort required for the BKS to maintain the automatic rebroadcasts.

In addition to the benefits described above, reduction in the number of services also increased the first-run capacity of the broadcast by reducing the proportion of messages that had to be rebroadcast as ZDK's. Table 8 illustrates this effect by showing the before-and-after demand represented by a first-run message, which was computed from TacCom Report data as the ratio

$$\frac{(\text{no. of first-run}) + (\text{no. ZDK})}{(\text{no. first-run})} \quad (7)$$

TABLE 8

REDUCTION IN DEMAND PRODUCED BY AUTOMATIC RERUNS

	Demand represented by one first-run message		Change in first-run capacity (percent)
	Before	After	
If the message were broadcast on PALD/RTT or PUSN*	1.078	1.045	+3.2
If the message were broadcast on PNSC	1.032	1.043	–3.3

These channels are combined, because a message first-run on one could have been rebroadcast as a ZDK on the other during this period.

The ratio in equation (7), then, shows the marginal increase in loading produced by the service mechanism as actually observed on the broadcast. It also takes into account the facts that not all of the service requests screened are rerun, and only a portion of those are actually rerun on the broadcast (since, e.g., broadcast ZDK's for units with full-period terminations are usually routed to the termination instead of the broadcast). Table 8 also shows the increase in first-run capacity produced by the change in demand, as computed from equation (6) of the previous section.

These results, then, show that:

The ZDK's on channels PALD/RTT and PUSN were reduced by the same proportion as the average number of service requests, but there was little effect on the ZDK's appearing on PNSC. Table 8 shows that the proportion of first-run messages appearing on channel (PALD/RTT and PUSN that were rebroadcast as ZDK's was reduced from 0.078 to 0.045, or 42 percent. Combining the figures for the average number of service requests for these 2 channels in table 7 shows that the service requests were similarly reduced from 1176.0 to 648.1 per day, or 45 percent. This is precisely the kind of correlation that would be expected. However, while the average number of service requests received on PNSC messages dropped about 16 percent (table 7), the demand represented by a first-run message actually increased about 25 percent. This is not, however, an unreasonable result. Many of the ZDK's on PNSC numbers are routed to the full-period terminations, and the number appearing on the broadcast may consequently fluctuate with the termination loading conditions.

The resultant decrease in demand increased the potential first-run capacity of PALD/RTT and PUSN about 3 percent. What this means operationally is that after the activation of automatic reruns, it would have taken a 3 percent increase in first-run traffic loading to produce same total loading on these channels as existed before automatic reruns were available. The additional capacity created by the reruns may not in itself seem significant, but it will be a consideration in the subsequent sections discussing duplication of transmissions caused by the Phase II and III subscribership realignments.

Phase II: Change in Guard and Routing for Terminated Units

As shown in table 2, the next step in the realignment was taken in mid-February 1970, when broadcast traffic for most major units with full-period terminations was diverted to PNSC, and their requirement to guard the first 4 channels of the broadcast was waived. Unlike the activation of automatic reruns, this change did not take place overnight. Rather, to minimize the chance that a message would be missed because it was inadvertently misrouted while the communications station and message originators adjusted to the new procedures, most of the affected units continued to guard and maintain files on the other broadcast channels for several weeks after the implementation date.

Because there was no clear-cut initiation date and because this step was not expected to greatly affect service activity, no data on service activity was collected immediately before or after Phase II was initiated. By the time it was decided to analyze this phase of the realignment for the sake of completeness, the necessary TacCom reports had been destroyed. However, it was possible to retrieve the necessary data from March 1970 to determine the service activity as it existed shortly after all major units should have secured channels 1-4, and to compare it with the data from post-Phase I period (6 October-1 November 1969) to produce the results which follow.

Table 9 summarizes the before-and-after comparison of loading conditions and service activity for the periods compared. Since the diversion of broadcast traffic for most major units to PNSC produced changes in both the traffic volumes routed to each channel and the number of subscribers to each channel, it is difficult to adjust these figures to produce an equal-basis comparison of service activity, as was done for Phase I.

Non^theless, examination of this table suggests the following general effects of Phase II of the realignment:

While the service request rate on channels PALD/RTT and PUSN was essentially unchanged, the number of service requests received for messages transmitted on these channels decreased substantially. As can be seen from table 9, the service request rate for PALD/RTT decreased only 10 percent between October 1969 and March 1970. At the same time, the number of service requests per 1000 first-run messages and the number of requests per day dropped about 20 percent as a result of the reduction in the number of subscribers. This illustrates the effect that a reduction in the number of subscribers to a channel can be expected to have on service activity.

The effect is particularly dramatic in the case of PALD/RTT, considering, e.g., that without reducing the number of subscribers to this channel as shown in table 9, the increase in traffic on PALD/RTT would have produced an average number of service requests per day more like 674,

TABLE 9

COMPARISON OF BROADCAST ACTIVITY FOR BEFORE AND AFTER PHASE II

		Channel			
		PALD/RTT	PUSN	PNSC	Overall
Average number of first-run messages per day	Before	565.9	438.2	250.0	1254.1
	After	616.0	299.5	286.8	1202.4
	Change	+8.4%	−31.7%	+14.7%	−4.1%
Average number of subscribers	Before	86.8	48.9	12.3	--
	After	74.7	45.7	13.3	--
	Change	−12.7	−3.2	−1.0	--
	Percent	−14.6%	−6.5%	+0.9%	--
Number of service requests per day	Before	542.3	247.9	95.2	885.4
	After	445.3	152.2	135.6	733.1
	Change	−17.9%	−38.6%	+42.4%	−17.2%
Number of service requests per 1000 first-run	Before	851.8	502.9	338.5	627.5
	After	662.6	465.9	433.5	559.0
	Change	−22.2%	−7.4%	+28.1%	−10.9%
Service request rate	Before	.010	.010	.028	.011
	After	.009	.010	.033	.011

rather than the 445 shown in the table. Because the traffic volume on PUSN decreased substantially and the overall change in the number of subscribers shown in table 9 is not as great as for PALD/RTT, the effects of Phase II on the PUSN service activity are not as obvious from the table. Assuming that the average of 45.7 subscribers shown for the post-Phase II period combines an increase in the number of subscribers over the October 1969 figure with a subsequent reduction by 13.3 subscribers as a result of Phase II, it can be estimated that there would have been an average of 55.2 subscribers to PUSN in March were Phase II not in effect. In this case, the number of service requests received on that channel each day would have been more like 184 instead of the 152 shown in table 9. It is not clear that the decrease in PUSN traffic volumes between October and March was wholly due to the realignment. But had traffic volumes on PUSN remained at the October levels for the 55 subscribers, the average daily number of PUSN service requests in March would have been closer to 299 than the 152 shown in table 9.

For equivalent total first-run volumes, the average daily number of service requests decreased by at least 17 percent. As shown in the "Overall" column of table 9, there was less than 5 percent difference in the average first-run traffic loads for the two periods compared, while the average daily number of service requests in March 1970 was 17.2 percent lower than in October 1969. Since the overall service request rate for these two periods was exactly the same, it is reasonable to conclude that the decline in the number of service requests was a direct result of the Phase II realignment. The 17 percent figure must, however, be considered a lower bound on the effect of Phase II because:

- The first-run volume, the number of subscribers, and the service request rate for PNSC were all greater in March. As can be seen from table 9, the combined effect of these increases was to increase the average daily number of service requests received on PNSC messages by 42 percent, negating part of the improvement on the other channels. While the increase in traffic volume on PNSC may have been due to the Phase II realignment, neither the change in number of subscribers nor the change in the service request rate can be reasonably attributed to the realignment. Consequently, the 17 percent decrease in number of service requests cited above must be considered to be lower than the full potential of the Phase II procedures.
- The average number of subscribers to PUSN in March was higher than it would have been had Phase II been implemented in October. If the number of subscribers to PUSN just before the realignment were the same as during October, and if every major unit stopped copying PUSN in mid-February, the before-and-after difference in the number of subscribers to PUSN shown in table 9 would have been 13 instead of 3. This means either the average number of subscribers to PUSN increased by about 10 between October 1969 and March 1970, or not all of the major units had stopped copying PUSN by March. The first alternative has already been considered to show that the reduction in the average number of service requests would have been greater had the number of subscribers remained the same; the latter alternative suggests that the full potential of the Phase II realignment had not yet been attained in March. In either case, the indication is that the potential reduction in the number of service requests from Phase II is greater than the 17 percent shown in table 9.

As a final observation on the effects of the Phase II realignment, table 10 compares the demand represented by a first-run message for October 1969 and March 1970. As can be seen, the demand represented by a first-run message appearing on channel PALD/RTT or PUSN changed very little. This was to be expected, since Phase II affected only major units with full-period terminations. These units seldom received ZDK's via the broadcast. The decrease in demand for PNSC shown in table 10 should not be considered to be a realignment effect; rather, it is probably largely due to the change in routing doctrine produced by STROFAC.

TABLE 10

CHANGES IN DEMAND REPRESENTED BY ONE FIRST-RUN MESSAGE BETWEEN OCTOBER 1969 AND MARCH 1970

	Demand		
	Before	After	Change in capacity
Message delivered on			
PALD/RTT or PUSN	1.045	1.044	--
PNSC	1.043	1.010	+3.3%

Phase III: Assignment of Channels 1-4 by Ship Type

The final step in the recommended realignment was implemented on 19 August 1970 by modifying the broadcast routing procedures to divert all traffic for destroyer force units to channels 1 and 2 (PASW and PSPC). In this scheme, PASW was designated as the first-run traffic channel; PSPC, whenever it was not required as an overload, was set up to carry automatic rebroadcasts of PASW traffic. At the same time, the extra capacity produced on channels 3 and 4 (PALD/RTT and PUSN) enabled the communications station to extend the coverage of automatic rebroadcasts by running first-run traffic primarily on PALD/RTT and using PUSN as an automatic rerun channel whenever possible. By adopting these procedures (as well as Phase II), guard requirements for all WestPac multichannel broadcast subscribers were reduced from all channels permitted by equipment limitations to 2 channels. Moreover, one of these channels was used to provide automatic reruns whenever possible. The final allocation of channels is shown in table 11.

TABLE 11

ALLOCATION OF BROADCAST CHANNELS UNDER THE FULL REALIGNMENT

Ship type	Primary traffic channel	Overload/rerun channel
Major unit with full-period termination	PNSC	PHIC
Destroyer force units	PASW	PSPC
All other multichannel subscribers	PALD*	PUSN
Single-channel subscribers	PRTT*	None

**Simulkeyed*

To estimate the effects of this measure on service activity, data from 1-18 August 1970 was compared with that from 19 August-2 September. The results of this comparison are shown in table 12. In addition, for discussion purposes, table 13 shows the change in the number of subscribers to the channels affected by the realignment. Since the data was taken from contiguous time periods, most of the changes shown in these tables can be attributed to the realignment.

Examination of these results suggests the following effects of Phase III:

Extension of a capability for copying automatic reruns to the remaining multichannel subscribers further reduced service request rates on the channels affected by about 40 percent. As can be seen from table 12, service rates for the primary traffic channels dropped 40 percent on PALD/RTT. Comparison of the service request for PUSN, a primary traffic channel before the realignment, with PASW, the destroyer force traffic channel after, showed a similar drop in the service request rate – about 37 percent. The corresponding reductions in the service date due to Phase I were (from table 7) 47 percent and 58 percent, respectively. Considering that fewer than half of the multichannel subscribers could copy automatic reruns after Phase I, this is about the magnitude of the reduction in service request rates expected as a result of this step.

TABLE 12

COMPARISON OF SERVICE ACTIVITY BEFORE/ AFTER THE PHASE III REALIGNMENT

		Channel			
		PALD/RTT	PUSN(PASW)*	PNSC	Overall
Service request rate (SRR)	Before	.010	.019	.068	.017
	After	.006	.012	.054	.012
	Change	−40.0%	−36.8%	−20.6%	−29.4%
Average number of requests per day	Before	383.5	269.5	286.8	939.8
	After	116.6	93.1	147.9	357.3
	Change	−69.6%	−65.5%	−48.4%	−62.0%
Average number of requests per 1000 first-run messages	Before	692.5	914.3	944.9	815.7
	After	222.2	233.3	976.2	332.5
	Change	−67.9%	−74.5%	+3.3%	−59.2%

**As a result of Phase III, PASW became a primary traffic channel and PUSN became a rerun channel.*

At the same time, table 12 shows that the service request rate on PNSC dropped 20 percent during the same period; and this channel should not have been affected by Phase III. This could mean that the 40 percent reduction cited above is inflated because of some change in propagation conditions. However, the more likely explanation is that this change results from subscribers' responding to the admonition in the directive for Phase III to try to use automatic reruns in lieu of service requests to pick up missing messages.

Combination of the reduction in the service request rate with the reduction in the number of subscribers to the channels affected produced a 70 percent reduction in the number of service requests received on these channels. The size of the reduction in the number of service requests is clear from table 12. How this decrease was produced as a combination of effects can be illustrated by also considering the changes in the average number of subscribers shown in table 13. Recall from equations (2) and (4) that the average number of service requests per first-run message, N, can be expressed as

$$N = \frac{R}{M} = SRR \times S, \tag{8}$$

where R = total number of service requests, M = the number of subscribers, and SSR = the service request rate.

Using the subscripts B and A to denote values of these factors before and after Phase III, table 12 shows for PALD/RTT that $SRR_A = (0.6)SRR_B$, and table 13 shows $S_A = (0.5)S_B$. Using these values and (8), we get that

$$\begin{aligned} N_A = SRR_A \times S_A &= 0.6\ SRR_B \times 0.5\ S_B \\ &= (0.30)\ (SRR_B \times S_B) = 0.30\ N_B; \end{aligned} \tag{9}$$

i.e., the number of service requests per 1000 first-run messages on PALD/RTT after phase III should have been 70 percent smaller than the number befo-. This result agrees well with the 67.9 percent reduction observed. A similar calculation for PUSN, compared to PASW, shows that

$$N_A = (.63)SRR_B \times (.42)S_B = (.26)N_B, \tag{10}$$

or the number of service requests per 1000 messages on PASW after Phase III should have been 74 percent lower than before. This figure also agrees well with the figure in table 12.

TABLE 13

AVERAGE NUMBER OF SUBSCRIBERS TO BROADCAST CHANNELS AFFECTED BY THE PHASE III REALIGNMENT

	Channel	
	PALD/RTT	PUSN(PASW)
Before	69.9	48.1
After	34.8	20.2
Reduction	−50.2%	−58.0%

As might be expected, the substantial reduction in service activity produced by this phase of the realignment produced, in turn, a substantial reduction in demand represented by a first-run message, but relatively little increase in potential capacity (because of the gains that had already been made by Phases I and II). This situation is illustrated in table 14, which shows that potential capacity was increased only 1.6 percent on PALD/RTT and PUSN(PASW) combined, even though the proportion of messages rerun as ZDK's on these channels was reduced from .043 to 0.27, or 37 percent.

TABLE 14

CHANGES IN DEMAND REPRESENTED BY A FIRST-RUN MESSAGE RESULTING FROM PHASE III

	Demand represented by one first-run message		Increase in first-run capacity (percent)
	Before	After	
Message run on			
PALD/RTT	1.042	1.017	2.5
PUSN(PASW)	1.044	1.041	0.3
Either channel	1.043	1.027	1.6

Effect Of Overall Realignment on Service Activity

The preceding discussions examine separately each step in attaining the recommended realignment to show its effect on the then current service activity. One view of the overall effect of these steps is contained in table 15, in which the service activity during 1-14 September 1969 is compared with that during 19 August-2 September 1970.

While the improvements shown in table 15 are impressive, even they may not truly represent the realignment potential. In the interval between these periods other changes in the broadcast characteristics occurred. Subscribers were changed as units deployed in the WestPac area rotated; the STROFAC routing concept became operational and gradually changed traffic distribution between the broadcast and full-period terminations; changes in the operational situations affected the amount and composition of the first-run traffic; and so on.

TABLE 15

SERVICE ACTIVITY: PRE-PHASE I AND POST-PHASE III

		Channel			
		PALD/RTT	PUSN(PASW)	PNSC	Overall
Service request rate	Pre-I	.019	.024	.037	.022
	Post-III	.006	.012	.054	.012
	Change	68.5%	-50.0%	+31.5%	-45.5%
Average number of requests per day	Pre-I	644.9	531.1	118.9	1294.9
	Post-III	116.6	93.1	147.9	357.5
	Change	-81.9%	-82.5%	+19.6%	-72.4%
Average number of requests per 1000 first-runs	Pre-I	1260.2	1210.1	517.4	1096.9
	Post-III	222.2	233.5	976.2	332.5
	Change	-82.4%	80.7%	+47.0%	-69.7%

Possible effects of such variations in the system become particularly apparent when the sequence of service request rates from the sample periods is considered. Observe from table 16, e.g., that the service request rates for PUSN and PNSC rose substantially between March and August 1970. While some of the increase may be attributable to a decrease in the use of the automatic rebroadcasts as communications pressures in the area eased, it is probably more reasonable to conclude that these and the other fluctuations in the table merely reflect the dynamic nature of the broadcast.

In view of this, it is tempting to combine the effects observed at each step of the realignment to produce an overall estimate of the change in the various measures of service activity that would have occurred had the 1-14 September traffic been rerun under the full realignment. Table 17 shows the results of such a comparison. As can be seen, the potential effect of the total realignment estimated in this fashion is, in some instances, considerably greater than that actually observed in the table 15 comparison.

TABLE 16

SEQUENCE OF SERVICE REQUEST RATES OBSERVED

Sample period	Channel			
	PALD/RTT	PUSN(PASW)	PNSC	Overall
1-14 Sep 1969	.019	.024	.037	.022
5 Oct – 1 Nov 1969	.010	.010	.028	.011
1-31 Mar 1970	.009	.010	.033	.011
1-18 Aug 1970	.010	.019	.068	.017
19 Aug – 2 Sep 1970	.006	.012	.054	.012

TABLE 17

HYPOTHETICAL EFFECT OF THE FULL REALIGNMENT ON SERVICE ACTIVITY DURING 1-14 SEPTEMBER 1969

		Channel			
		PALD/RTT	PUSN(PASW)	PNSC	Overall
Service request rate	Before	.019	.024	.037	.022
	After	.003	.006	.011	.006
	Reduction	–85.1%	–73.6%	–68.9%	–72.7%
Average number of requests per day	Before	644.9	531.1	118.9	1294.9
	After	47.9	58.9	37.0	143.8
	Reduction	–92.6%	–88.9%	–68.9%	–88.9%
Average number of requests per 1000 first-run messages	Before	1260.2	1210.1	517.9	1096.9
	After	89.3	134.3	161.1	122.9
	Reduction	–92.6%	–88.9%	–68.9%	–88.8%

As the final point in the considerations of the overall effect of the realignment on service activity, table 18 summarizes the overall changes in the demand characteristics of the broadcast between the pre-Phase I period and the post-Phase II period. The reduction in service activity reduced the proportion of first-run messages rerun as ZDK's from 0.78 for messages first-run on either PALD/RTT or PUSN to 0.17 for messages on PALD/RTT and 0.041 for messages first-run on PASW, or 78 percent and 47 percent, respectively. The resulting increase in first-run capacity was 6 percent on PALD/RTT and 4 percent on PUSN. Combination of these results shows that these gains could have offset a 5 percent increase in the amount of first-run traffic destined for PALD/RTT and PASW.

Table 18 also shows the change in demand on PNSC over the same periods. While the figures show that the proportion of first-run messages rerun as ZDK's on this channel dropped to zero after the realignment was completed, not all of this decrease can be directly attributed to the

TABLE 18

OVERALL CHANGE IN DEMAND AND CAPACITY PRODUCED BY THE REALIGNMENT

	Demand represented by one first-run message		Increase in capacity (percent)
	Before	After	
Message first-run on			
PALD/RTT	1.078*	1.017	6
PUSN(PASW)	1.078*	1.041	4
Either channel	1.078	1.027	5
PNSC	1.032	1.000	3

**Prerealignment values for these channels are the same, because ZDK's from one channel could appear on the other.*

reduction in service activity. The more dominant factor in producing this change was probably the exclusive use of the STROFAC routing indicators for the terminated units that subscribe to PNSC, which diverted all traffic including broadcast ZDK's to the terminations.

REDUCTION OF BROADCAST WORKLOAD

In the preceding section, the effects of the realignment on service activity are examined in detail to show how well it met its primary objective. However, the results presented there show only part of the effect. The realignment also produced reductions in workload created by the broadcast both aboard the subscribing units and, eventually, at the communications station, which would have justified adoption of the realignment even had its effect on service activity been minimal. These effects are discussed below to show that this or similar realignments should be considered for other areas even if the level of service activity is not burdensome.

Reduction of Shipboard Workload

As indicated earlier, before Phases II and III of the realignment were implemented, each WestPac broadcast subscriber was required to guard every channel that it was equipped to copy. After these procedures were implemented, each subscriber was required to copy only one channel full-time and a second channel only when it was activated for overload traffic or when it was necessary to guard the automatic reruns for missing numbers. To illustrate the effect of this change in routing doctrine, the actual number of channels guarded and the average daily volume of first-run traffic copied for various types of subscribers from 6 October to 1 November 1969 was compared with hypothetical numbers calculated by estimating what these loads would have been had the full realignment been implemented on 15 September. While a direct comparison of the pre- and postrealignment data may seem to be the more natural vehicle for this comparison, this choice was motivated by the following considerations:

- First-run traffic loads on the primary traffic channels after the automatic reruns were adopted more fairly represent the total load, because occasional use of overload channels PASW, PSPC, and PHIC for first-run traffic was almost entirely terminated during this period, while the BKS tried to maintain a continuous schedule of automatic reruns.
- STROFAC routing procedures had not yet been adopted, so the PNSC traffic loads during this period did not reflect the effects of diverting broadcast traffic for PNSC subscribers to their full period terminations.
- There were no multiple transmissions of messages during this period to confound determining the proportion of traffic delivered via each channel.

The hypothetical first-run traffic volumes were estimated by combining data from two sources:

- First the proportion, V_i, of the total first-run volume carried by a primary traffic channel, i, was estimated for PALD/RTT, PUSN, and PNSC from the data for 6 October-1 November 1969 contained in table B-1 (appendix B).
- Next estimates of T_{ij}, the proportion of traffic on channel i that would have been transmitted on channel j, for PALD/RTT and PUSN were taken from table VII of reference (f), which summarizes a study of 900 messages broadcast in July 1969; $T_{PNSC,\ PNSC}$ was set equal to 1, since nearly all traffic on PNSC before Phase II was addressed exclusively to PNSC subscribers.

The proportion, P_j of the total first-run volume that would have been routed to channel j under the realignment, was then calculated as the sum of products of the form

$$P_j = \Sigma_i \, T_{ij} \cdot V_i. \qquad (11)$$

The values used in this calculation are summarized in table B-5 of appendix B.

The P_j values obtained from equation (11) were then multiplied by 1254, the average daily first-run volume for 6 October-1 November 1969 to produce estimates of the average daily volume that would have been carried on each primary traffic channel under the realignment; volumes for ship types were derived by deciding which primary traffic channel the unit would have copied under the realignment.

The results of this comparison are summarized in table 19, which shows, e.g., that about 88 percent of the destroyers were equipped to copy channels 1-4; these units received an average of 1004.1 first-run messages a day on 4 channels before the realignment, but would have received only 499.1 (50.3 percent fewer) on 2 channels had the realignment been in effect. While this comparison is somewhat idealized, it illustrates the magnitude of the reduction in broadcast workload throughout the fleet that was produced by the realignment. Direct benefits of this reduction of workload are cited in the message excerpts in appendix A.

Reduction of Communications Station Workload

While the decline in communications station workload resulting from the 70 percent reduction in the number of service requests cannot be considered only a minor improvement, the more

TABLE 19

HYPOTHETICAL COMPARISON OF BROADCAST WORKLOADS BEFORE AND AFTER THE REALIGNMENT

Unit capability type (percent with capability)	General traffic number of channels guarded		Average number of first-run messages copied each day	
Full multichannel suit:				
CA, CVA, LPH (All)	Before	6		1254.1
DLG's (All)	After	2		489.1
			Reduction	61.0%
Channels 1-4 only:				
Destroyers (88%)	Before	4		100.4
	After	2		499.1
			Reduction	50.3%
Servforce units (26%)	Before	4		1004.1
Phibforce units (75%)	After	2		578.1
			Reduction	42.4%
Channels 3 and 4 only:				
Servforce units (37%)	Before	2		1004.1
Phibforce units (8%)	After	2		578.1
Mineforce units (90%)			Reduction	42.4%
Single channel only:				
Destroyers (12%)	Before	1		565.9
Servforce units (37%)	After	1		578.1
Phibforce units (16%)				—
Mineforce units (10%)				

significant reduction in workload for the BKS (broadcast keying station) resulting from the realignment was the change in the processing of broadcast messages that the allocation of channels by ship type enabled. Before the realignment, a message destined for the broadcast was routed to a central point in the BKS message center, where each addressee on the message was checked against a master guard list to determine which channels of the broadcast the intended recipients guarded. This determined a set of possible channels for delivery from which one was selected. The selection was usually made on the basis of the apparent backlogs existing on the various channels, but sometimes it was done arbitrarily. It is not hard to see that this manual segregation technique was time-consuming, produced a processing bottleneck, required one or two persons per watch for its maintenance, and could often create a situation in which messages were routed to a channel that had a greater backlog than an alternative channel.

After Phase III of the realignment, however, subscribership to each broadcast channel was completely determined by the unit type, as shown in table 11. Because of this one-to-one correspondence of ship type and primary broadcast traffic channels, it became possible to promulgate a set of worldwide routing indicators that designated the appropriate broadcast channel for each subscriber (see table 5). Since the worldwide routing indicator usually appears adjacent to the addressee name in a message, this change in itself should have greatly facilitated the manual routing, for it eliminated (as long as it was continued) the need to check each message against the master guard list.

More importantly for the longer term, these routing indicators can be read by the communications station MAPU's (Message Automatic Processing Units) to automatically distribute a tape copy of a message to a remote terminal*. Thus, by reconfiguring the message center to set these remote terminals adjacent to the appropriate broadcast keying unit, NCS Guam was able to completely eliminate manual segregation when it assumed broadcast keying control from NCS Philippines. Not only did this release message center personnel formerly used as broadcast routers for other duties, it greatly speeded up the processing of broadcast messages.

TRAFFIC DISTRIBUTION

The routing of traffic by ship type under the realignment produced, in addition to its beneficial effects, changes in the distribution of traffic among the various primary traffic channels that might have created problems. The proportion of traffic routed to a given channel became a function of traffic composition by addressee type rather than of handling procedures at the BKS, and the segregation of traffic channels necessitated multiple transmission of messages addressed to units guarding different channel sets. These effects are analyzed below to show that neither represented a real difficulty after the realignment was implemented.

Distribution of Traffic Among Channels

Concern over the distribution of traffic among the various channels after the realignment arose from the possibility that one channel set might, because of its subscribership, be required to carry a disproportionate share of the load. Under very heavy loading conditions, such an unequal distribution could produce a situation in which the more heavily loaded channel set would be backlogged while the others were running below capacity. Table 20, which compares pre-Phase I and post-Phase III distribution of first-run traffic to the primary traffic channels shows, in fact, that the distribution of traffic among the various channels was virtually unchanged. The only possible substantial difference was a decrease in the proportion of traffic carried by PNSC, and this is

TABLE 20

PRE- AND POSTREALIGNMENT DISTRIBUTION OF FIRST-RUN TRAFFIC

Channel	Portion of the total first-run volume carried	
	Before realignment	After realignment
PALD/RTT	.434	.488
PUSN(PASW)	.372	.371
PNSC	.195	.141

*The natural extension of this automatic routing concept is to bridge the step through the MAPU's and drive the broadcast directly from the AUTODIN (Automatic Digital Switching Network), which delivers the messages to the communications station to take advantage of the computer-controlled precedence queues. This was tried on an experimental basis at NCS Honolulu with good results.

probably due to STROFAC rather than the realignment. This shows that *the realignment did not adversely affect the distribution of traffic among the primary traffic channels.*

Multiple Transmissions

As a result of traffic-channel segregation under the realignment, some proportion of the messages routed to the broadcast must be transmitted on more than one channel because they are addressed to different ship types. Such duplicates are not a concern as long as the traffic is automatically routed, so that transmission tapes do not have to be duplicated. Nor are they a concern as long as existing capacity is sufficient to handle existing demand. But such duplication may reduce the overall capacity of the broadcast and must be considered as a potentially degrading aspect of the realignment.

The original feasibility study estimated that the amount of increase in the total number of transmissions that would result from multiple transmission of messages routed to 2 or 3 channels would be about 27 percent of the number of first-run messages destined for PASW and PALD/RTT, or about 24 percent of the total number carried on the broadcast. The breakdown of the expected sources of these additional transmissions is shown in table 21, from which it can be seen that about 40 percent of the additional transmissions were anticipated to arise from duplications between PASW and PALD/RTT. The rest were anticipated to result from duplications between PNSC and the other channels.

TABLE 21

MULTIPLE TRANSMISSION EFFECTS PREDICTED BY THE FEASIBILITY STUDY

	Proportion of messages routed to PALD/RTT or PUSN
Transmitted both on PASW and PALD/RTT	.112
Also routed to PNSC	.161
Increase in total transmissions	27.3%

In a follow-on study conducted at CINCPACFLT in June 1970 after Phase II had been implemented, the original estimate of duplications between PASW and PALD/RTT was further substantiated. That study showed that of the 3107 messages broadcast on PALD/RTT and PASW over 22-25 June, only 11.4 percent would had to have been transmitted on both channels if Phase III had been in effect at that time.

Examination of the data in appendix B of this study shows that PALD/RTT and PUSN together carried an average of 848 first-run messages a day immediately before Phase III, and PASW and PALD/RTT together carried an average of 924 a day immediately afterward. Thus, assuming no

substantial change in demand between the pre- and post-Phase III sample periods so that the increase observed was solely due to multiple transmissions, it appears that 76 of the 848 messages (about 9 percent) destined for these 2 channels each day had to be transmitted twice because of channel segregation.

Since the three independent estimates cited above are all close, it is reasonable to conclude that only about 10 percent of the messages destined for PASW or PALD/RTT after the Phase III realignment had to be transmitted on both channels. At the same time, as shown in table 18, the reduction in ZDK traffic increased the potential first-run capacity on these 2 channels about 5 percent, partially offsetting the magnification of demand caused by the multiple transmissions of messages destined for these channels.

In the case of PNSC, it is nearly impossible to estimate the impact of multiple transmissions. The problem here is that the STROFAC routing procedures diverted much of the traffic for this channel to full-period terminations. As a result, the increase in the average number of messages broadcast on PNSC (from 250 before Phase II to 287 after Phase II, shown in appendix B) suggests only a 15 percent increase in the number of messages routed to PNSC as a result of its segregation from the other channels. The feasibility study in reference (f) predicted a threefold increase in demand. In any case, as table 20 shows, deletion of the broadcast routing indicator from the worldwide routing guides eventually changed the role of PNSC to such an extent that the effect of multiple transmissions on this channel could no longer reasonably be a matter of concern.

The preceding observations, then, support the following conclusions about the impact of the multiple transmissions:

As a result of channel segregation, the amount of traffic carried by PASW and PALD/RTT increased about 10 percent; half of this increase was offset by reduction of ZDK traffic.

Because of STROFAC, the great increase in demand for PNSC anticipated from the feasibility study never materialized.

DISCUSSION

The preceding analyses show that allocation of broadcast channels by ship type and use of automatic rebroadcasts produced great improvements in the WestPac broadcast. Service activity was substantially reduced, shipboard workloads were halved, and a viable system of automatically routing traffic to the various channels was created. Since these improvements were produced within the existing system at no cost in material or personnel, the results also demonstrate the extent to which broadcast system performance depends on the operating doctrine governing its use. It is therefore appropriate to conclude this study with a review of the procedures that were producing the problems in WestPac and a discussion of general guidelines for improving broadcast doctrine that might be applied in other communications regions. In doing so, three broad management areas are dealt with: ZFG management, channel usage, and capacity-effectiveness trade-offs.

ZFG MANAGEMENT

The use of surplus capacity to broadcast voluntary reruns (ZFG's) of messages is an accepted practice in all communications areas. Unfortunately, such reruns are often ineffective because lack of management by the shore station fails to instill shipboard operator confidence necessary to make them effective. ZFG management in WestPac before the realignment exhibited three weaknesses:

- ZFG's were not timely. As shown, 90 percent of the WestPac ZFG reruns were transmitted more than 5 hours after the first run; 95 percent of the service requests were originated within 5 hours of the first run. This disparity produced a situation in which the ZFG's were neither faster nor more convenient than the other service alternatives.
- ZFG traffic was haphazardly selected. Before the realignment, there was a tendency to rebroadcast the handiest messages available with little regard for their usefulness or effect. An example of this was rerun four times in one day at intervals of 3½, 6½, 9½, and 13 hours after the first run.
- ZFG schedules were not predictable. Because of the random selection of traffic for voluntary rerun and the sporadic appearance of surplus capacity, ZFG reruns were appearing on the broadcast anywhere from 4 to 18 hours after the first run. With such a wide distribution of retransmission times, the shipboard operator had no idea of when to expect a ZFG rerun, if it were to appear, and did not know when to stop looking for it. Consequently, few operators even bothered to screen ZFG's for their missing numbers when the ZFG's did appear.

The alternative to practices such as these, which negate the usefulness of ZFG's, is to institute a management system that guarantees timeliness and predictability of ZFG's. Since there was sufficient capacity for them in WestPac, the automatic reruns were the method of choice there. However, informal analyses conducted in other communications areas suggest that almost any ZFG management system can produce the desired results if it ensures that ZFG reruns appear on the broadcast within 2 hours of their first run or not at all, and that shipboard operators can readily determine when ZFG's of their missing numbers may appear.

As witnessed by the WestPac experience, the maintenance of a ZFG management system is worth the effort. When properly managed, ZFG's can be an effective tool in reducing service

activity. However, this is but part of the picture. More important than the reduction in service activity that can result from effective use of ZFG's is the reduction in delivery times for messages missed on the first run. A missing number picked up from a timely ZFG rerun has been delivered anywhere from two to 10 times faster than would have been possible had the ZDK service mechanism been used. Thus, even when a communications station is not feeling pressure from inordinate service loads, much can be gained by avoiding mistakes such as those that were being made in WestPac, and by ensuring that ZFG traffic is managed in a way that makes it useful.

CHANNEL USAGE

Multichannel Broadcast

The multichannel broadcast appears to have a full 6-channel, general service capacity. The historical management policy has been to try to preserve this full capacity by assigning channels in a way that enables the communications station to effect delivery of a message with one transmission. Thus, under the prerealignment routing doctrine in WestPac, channels 3 and 4 were designated as primary traffic channels to be guarded by all units. The other channels were designated as overload or additional channels to be continuously guarded by all units capable of demodulating the signals. Under this system, it appeared that the full capacity of the broadcast was preserved while the channel selection problem was minimized.

In fact, the notion of preserving full capacity this way is fallacious, because the actual capacity represented by a given channel depends on shipboard equipment limitations and message addressing patterns. To visualize this, consider channels 1 and 2 in the prealignment scheme. The actual capacity represented by these channels was not the volume they could carry but the proportion of the incoming traffic that was addressed exclusively to units with the channel 1 and 2 demodulation capabilities. So if channels 1 and 2 could have, theoretically, carried 1000 messages a day between them, but the day's incoming broadcast traffic contained only 250 messages addressed exclusively to units copying these channels, the maximum capacity represented by channels 1 and 2 combined was 250 messages, not 1000. The remaining 750-message capacity simply could not have been used.

Once this subtle distinction is appreciated, a routing doctrine like that used in WestPac before the realignment is seen to be highly undesirable. In an attempt to preserve what may be only illusory capacity, these disadvantages are produced:

- With existing equipment, the communications station must manually route overload traffic. Since the existing automatic routing system (the MAP) cannot distinguish multiply-addressed messages, the intervention of a broadcast router to manually screen for those messages that can be delivered on channels with limited subscribership is necessary to divert messages to the overload channels. This is both time- and personnel-consuming.
- Some broadcast subscribers are required to guard more channels than really necessary. To support the prerealignment routing doctrine, units had to guard every channel they could demodulate, while the amount of traffic of interest received represented little more than one channel's worth of information. Thus, more TTY and crypto equipment had to stay on the line, and there was less opportunity for maintaining preventive maintenance schedules and little or no back-up capability.

• From the viewpoint of the subscriber, the existing capacity is inefficiently used. As the number of subscribers to a given channel increases, the probability that any given message appearing on that channel will be of interest to a given subscriber decreases. Therefore, more manpower, paper, and equipment are expended per message of interest, and shipboard broadcast files become much bigger than necessary.

The alternative of assigning channels on the basis of ship type, as was done in WestPac, is one way to improve routing doctrine and avoid the disadvantages of a "one-transmission-per-message" philosophy. While many other alternatives exist which may be better for other communications regions, the WestPac experience suggests that any permanent assignment of broadcast channels should share the following features with the WestPac realignment.

The routing doctrine should be keyed to the most stable subscribership characteristic. In segregating broadcast channels for use by different sets of subscribers, it is clearly desirable to develop a routing doctrine that can be implemented automatically. To do this efficiently, it is necessary to key the routing on characteristics that are stable from day to day, so that changes in the routing system are infrequent. Otherwise, the problems of educating message originators and of mis-routes occurring during changeover periods will negate the benefits of the automatic routing system.

Three possibilities were considered in WestPac: routing by content, routing by task force/task group or area of operation, and routing by ship type. Since there is no clearly established relationship between message content and addressees, routing by content cannot be implemented automatically without requiring overlapping channel subscribership, much as existed before the realignment. Task force/task group routing is intuitively attractive, but task force composition and assignment change too frequently to provide a stable basis for routing, since each change in the task group assignment would require a guard shift. Thus, routing by ship type as a close approximation to task force/task group routing appears to be the only system that offers the invariance required to support automatic routing.

No channel should be underutilized as a result of the routing doctrine. The prerealignment routing doctrine in WestPac underutilized the designated overload channels on two counts: Shipboard equipment limitations prevented their full use when they were activated, and no provision was made for the idle-time use of these channels when they were not required for overloads. Such built-in underutilization is a waste of capacity that can be avoided by balancing the traffic distribution among primary traffic channels and using secondary channels for automatic rebroadcasts.

Single-Channel Broadcast

As a final point in the consideration of channel allocation, we consider the single-channel broadcast. Though this system is gradually being phased out, a small number of units will probably be without the multichannel capability for quite some time, and it is worthwhile to consider the question of simulkeying this broadcast with a channel of the multichannel broadcast, as was done in WestPac before the realignment. Three benefits would thus accrue:

- The opportunity to utilize other ship services is enhanced. It was shown that as much as 75 percent of the messages missed on the first transmission could be picked up from other ship services, and that this source of missing numbers was substantially faster than communications station services. Simulkeying of the single-channel broadcast with a channel of the multichannel broadcast increases the number of units receiving the same messages and, therefore, increases the chance that another unit can supply a missing number. The increase in such opportunities for contact by simulkeying can reduce the service request rate as much as 20 percent.

- Multichannel subscribers copying the channel simulkeyed with the single-channel broadcast have better back-up capability. When a unit's multichannel demodulator fails for a long time, the general practice is to shift its guard to the single-channel broadcast. Such a guard shift can be made quite easily when the single-channel broadcast is simulkeyed with that unit's channel in the multichannel broadcast. Moreover, units copying the simulkeyed channel have the capability for additional diversity by copying both signals on separate equipments. This capability enables these units to copy the broadcast from different communications stations, thereby maintaining the broadcast on different geographical paths.

- Communications station workload is reduced. One tape reader instead of two is required to key both broadcasts when they are simulkeyed. This also reduces the number of files the communications station must maintain.

CAPACITY-EFFECTIVENESS TRADE-OFFS

In each of the steps of the WestPac realignment, including the simulkeying of the single-channel broadcast with channel 3 of the multichannel broadcast, improvements were produced by trading off some capacity for improved reliability, greater speed of service, or other benefit. Since the feasibility of these trade-offs is the criterion for adopting the recommended procedures in other areas, it is instructive to review them in detail to determine in each case exactly what was at stake.

Simulkeying

There were several trade-offs effected when simulkeying of the single-channel broadcast with channel 3 was initiated. On the negative side, the procedure increased demand on channel 3 by adding all messages addressed to only the single-channel subscribers. In addition, efficiency of the broadcast from the subscriber's viewpoint was reduced somewhat because a larger set of subscribers to the common intelligence channel was created, so both the single-channel and channel 3 subscribers had to copy more messages to receive their traffic of interest. In return for the loss in potential capacity and efficiency, service activity was reduced by enabling single-channel and multichannel subscribers to provide missing numbers for each other and creating a ready back-up capability for channel 3. Also, the number of communications station tape readers to be manned and files to be kept was reduced.

Since reduction of service requests and delays of service reruns was the primary concern in WestPac, the trade-off was considered worthwhile. Generally speaking, the decision to simulkey

must be determined by the answer to this question: *Does the increased load on the multichannel broadcast represent a difficulty?* If the additional load on a multichannel broadcast channel with which the single-channel broadcast is simulkeyed is great enough to produce significant and frequent backlogs, then the trade-off is simply not feasible. On the other hand, if it is possible to simulkey the single-channel broadcast without backlogging, then the loss in efficiency from the subscriber viewpoint is a relatively insignificant consideration, because:

- Subscribers copying the simulkeyed broadcast must maintain guard on at least one primary traffic channel, anyway; the difference in the number of messages copied does not create an additional manpower or equipment requirement.
- The number of multichannel subscribers will undoubtedly outnumber the number of single-channel subscribers, so the back-up capability afforded these units by simulkeying will be the more important consideration.

One word of warning is in order, however. In estimating whether the additional load will be unmanageable in an area where segregation of channels by ship type has been made, the additional load must also be considered in terms of what happens when traffic from a multichannel subscriber copying a different primary traffic channel must revert to the single-channel broadcast because of an extended UCC-1 outage. Such a shift will create additional demand on the simulkeyed broadcast that may be significant.

Automatic Rebroadcasts

The automatic rebroadcasts introduced in Phase I of the realignment must be considered essentially as "no cost" improvement. Admittedly, some effort is required at the communications station to ensure that the rebroadcasts are initiated on schedule. However, the effort required is little more than a more frequent change in reperforator tapes, which is far outweighed by the reductions in service activity and delay times for messages missed on the first transmission.

Thus, the only trade-off to be considered is when to activate the automatic rerun channel as first-run overload. This is a very complex problem, and a careful analytical examination of this question is beyond the scope of the study. (In fact, an exact answer requires the use of a computer simulation model that will be described in a forthcoming OEG study.) However, it is worthwhile to note here that occasional activation of the automatic rerun channel for first-run traffic can be beneficial. If the second channel is used exclusively for automatic reruns, it may not be used enough, or may not receive enough maintenance and tuning attention to provide good reception in a crisis when it is really needed.

Diversion of Traffic for Major Combatants to Channels 5 and 7

While reduction of broadcast guard requirements for major combatants may appear to reduce the capacity for delivering messages to these units, the WestPac experience suggests that full-period termination capacity is enough to handle the requirements for these units in an active operational environment. Moreover, three points should be considered in this regard:

- Because the full-period terminations are dynamically managed, delivery of high-precedence traffic on them will generally be faster and more reliable than on the broadcast. Whereas the broadcast must employ the service mechanism to ensure delivery of messages, verification of message delivery via a full-period termination is conducted in real time by QSL (receipt) procedures.
- Whenever the additional broadcast capacity for major combatants is required because of failure of the termination equipment or the imposition of EMCON (emission control), the automatic rebroadcast channels can still be preempted to activate a special broadcast.
- Similarly, if considered necessary or desirable, a major combatant can still voluntarily guard the other broadcast channels to provide services for ships in company. At the same time this service is provided, the major combatant is no longer constrained to maintain a complete broadcast file on the channels guarded for ships in company, so the workload involved is not as great.

Thus, there is very little real loss in capabilities when major combatants are removed from the other traffic channels, while the reduction in their broadcast workloads and elimination of their service requests for messages appearing on channels 1-4 benefit both the major combatants and the communications station. In this light, there really seems to be no trade-off, and these procedures stand as a "no cost" improvement.

Segregation of Traffic for Channels 1-4 by Ship Type

As the analysis of Phase III of the WestPac realignment shows, segregation of traffic channels offers great potential for improving broadcast effectiveness. Shipboard workloads can be halved, and the number of service requests received by the communications station can be reduced. In addition, if the segregation can be keyed to a stable indicator such as ship type, automatic routing to the broadcast becomes possible and delivery times substantially reduced.

Against these benefits, there is the possibility that some potential broadcast capacity may be lost because of the need to transmit messages on more than one channel. Although this question was a major concern in considering the feasibility of the WestPac realignment, closer scrutiny of the problem in light of experience with these procedures in WestPac and other areas suggests that the duplicate transmissions may not be as serious as originally envisioned, for several reasons:

The duplicate transmission, in fact, may not represent a loss in effective broadcast capacity. To illustrate this point, table 22 shows the traffic distribution that would result under various conditions when it is assumed that 90 percent of the traffic is jointly addressed to units of different types, and the remaining 10 percent split equally between these as singly addressed messages. (This is an extreme example, chosen to magnify the effects of the duplicate transmissions).

Observe, in this example, that when units of both types are equipped to copy both channels, each channel must carry a much larger load than is necessary to deliver the broadcast traffic. The total capacity of channels 1 and 2 is about halved by the duplicate transmissions. This represents a case in which the duplicate transmissions do reduce capacity. However, in the second case, when

TABLE 22

DISTRIBUTIONS OF A HYPOTHETICAL TRAFFIC LOAD UNDER VARIOUS CONDITIONS AND ROUTING DOCTRINES

Assumptions: 1. *Two ship-type classes: A and B*
2. *Two primary traffic channels: 1 and 2*
3. *Traffic composition: 90% addressed to units both from class A and from class B; 5% addressed only to units from class A; 5% addressed only to units from class B.*

Condition	Routing doctrine	Channel 1 load (percent)	Channel 2 load (percent)	Copied by A-type units (percent)	Copied by B-type units (percent)	Total (percent)
Both A and B units equipped to copy 1 and 2	All units copy all channels possible	50	50	100	100	100
	A units guard 1; B units guard 2	95	95	95	95	190
A units equipped to copy 1 only; B units equipped to copy 1 and 2	All units copy all channels possible	95	5	95	100	100
	A units guard 1; B units guard 2 only	95	95	95	95	190

A-type units cannot copy channel 2, there is no loss in effective capacity even though 90 percent of the traffic is transmitted on both channels and the apparent total load is nearly twice as large. The reason is that only a small amount of traffic can be routed to channel 2 under the "one-transmission-per-message" doctrine.

While "Case 1" in table 22 represents the kind of effect that generates concern over duplicate transmissions, "Case 2" is closer to the one that applies under the existing multichannel equipment distribution, since the majority of service force, amphibious force, and mine force units do not have the capability to copy all of the first four channels of the multichannel broadcast. Thus, it can be misleading to use the number of duplicate transmissions alone as the indicator of the loss in capacity due to the segregation of traffic.

If the routing doctrine enables automatic routing, duplicate transmissions do not represent an additional workload on the communications station. When Phase III of the realignment was initiated, the communications station was required to manufacture additional tapes for messages that had to be transmitted on more than one channel. However, after the communications station was reconfigured to accommodate automatic routing, the additional tapes were manufactured by the MAP tape units assigned to each channel, and no additional effort was required to support the system.

These observations, then, suggest that the criterion for adoption of a routing doctrine that segregates traffic channels should not be based on the number of duplicate transmissions. Rather, the question to be answered is: *Can traffic be routed to channels on the basis of ship type without creating significant backlogs on a channel that would not be backlogged under a "one-transmission-per-message" doctrine?*

Because of the improvements offered by the segregation of channels, an affirmative answer to this question justifies the adoption of the procedure regardless of the amount of duplication.

APPENDIX A

EXAMPLES OF DIRECT BENEFITS REALIZED ABOARD SHIPS FROM THE REALIGNMENT

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EXAMPLES OF DIRECT BENEFITS REALIZED ABOARD SHIPS FROM THE REALIGNMENT

In reference (a) of this appendix, ComSeventhFlt requested all major SeventhFlt commands to report noticeable changes in communications operations resulting from the realignment. The following excerpts from replies to that message illustrate some of the direct benefits realized aboard individual units:

- From CTF SEVEN THREE 140125Z OCT 70 (consolidated report from the SEVENTHFLT Service Force units):

" MUL BCST REALIGNMENT (FINAL PHASE) HAS PROVEN TO BE OF GREAT BENEFIT IN INCREASING BCST RELIABILITY' IT HAS RESULTED IN THE FOLLOWING: REDUCED MISSING NUMBER REQUESTS; REDUCED CONSUMPTION OF TELETYPE PAPER AND OTHER SIMILAR CONSUMABLES; ENABLED SHIPS TO TAKE EQUIP OFF THE LINE TO CONDUCT MUCH NEEDED PMS; REDUCED VOLUME OF NON-RELATED TRAFFIC HAVING TO BE SCREENED (FM OPERATOR'S VIEWPOINT); REDUCED NUMBERS OF REQUIRED FILES; AND FREED RM OPERATORS FOR OTHER TASKS"

- From CTF SEVEN SIX 151036Z OCT 70 (consolidated report from SEVENTHFLT Amphibious Force units):

" A. POSITIVE RESULTS OF BROADCAST REALIGNMENT:

1. REDUCTION IN MAN-HOURS REQUIRED FOR *OPERATION, MAINTENANCE*, AND FILING.

2. MORE MAN-HOURS AVAILABLE FOR PMS AND TRAINING.

3. LESS WEAR AND GREATER EQUIPMENT RELIABILITY DUE TO MORE EQUIPMENT BEING PLACED IN STANDBY STATUS.

4. PMS MORE EASILY CONDUCTED DUE TO INCREASED EQUIPMENT AVAILABILITY.

5. REDUCTION IN FILES AND FILE STORAGE SPACE REQUIRED.

6. SAVINGS IN CONSUMABLES SUCH AS PAPER, DITTO ROLLS, ETC.

B. NEGATIVE RESULTS OF BROADCAST ALIGNMENT: NONE REPORTED, OR NOTED."

- From CTG SEVEN ZERO PT FIVE 130621Z OCT 70 (consolidated report from SEVENTHFLT Mine Force Units):

" ...FOL ADVANTAGES OF REALIGNMENT NOTED:

A. TTY PRINTER HOURS REDUCED. CONSEQUENTLY MAINT MAN-HOURS REDUCED AND MORE ORDERLY APPROACH TO PREVENTIVE MAINT PERMITTED.

*B. RADIOMEN ABLE TO USE CONVERTER UNITS ON SINGLE CHNL WHILE REPAIRING/ALIGNING UCC-1.

C. AUTO RERUN GREATLY REDUCES OPERATOR TIME BY ALMOST ELIMINATING SVC MESSAGES FOR RERUN AND ZDK REQUESTS.

D. CONSUMABLE EXPENDITURES REDUCED BY ACTIVATING RERUN CKT ONLY WHEN NEEDED. REDUCTION FREES MUCH NEEDED STORAGE SPACE PARTICULARLY VALUABLE ON MSO."

- From CTG SEVEN ZERO PT EIGHT 140610Z OCT 70 (consolidated report from SEVENTHFLT Cruiser and Destroyer units):

"1. IN RESPONSE REF A ORIG QUERIED SUBORDINATES ON IMPACT WESTPAC MUL BCST REALIGNMENT AND BASED ON REPLIES THE FOLL CONSOLIDATED REPORT IS SUBMITTED:

**A. PEOPLE SAVINGS. PERMITTED RM PERSONNEL INITIATE THREE SECTION WATCH. IN ALL CASES UNITS REPORT A REDUCED BCST WORKLOAD THEREBY PERMITTING OPERATORS DEVOTE MORE TIME AND EFFORT IN CHECKING BCST CONTINUITY, FILING, FREQ. SURVEILLANCE AND QUALITY CONTROL. ADDITIONALLY THE REDUCTION IN CHANNELS COPIED CONTRIBUTED IN REDUCTION OF NOISE LEVEL THEREBY REDUCING PHYSICAL AND PSYCHOLOGICAL FATIGUE OF WATCH STANDERS.

B. DUPES. DUPLICATE MESSAGES HAVE BEEN REDUCED APPROXIMATELY THIRTY FIVE PERCENT.

C. EQUIPMENT MAINT AVAILABILITY. REALIGNMENT HAS REDUCED EQUIPMENT COMMITTED THEREBY PERMITTING REQUIRED PREVENTATIVE MAINT ON SCHEDULED BASIS.

D. COST EFFECTIVENESS. APPROX THIRTY PERCENT REDUCTION IN BCST CONSUMABLE SUPPLIES AND REPAIR/OVERHAUL OF EQUIP.

2. CONSIDER BCST REALIGNMENT UNQUALIFIED SUCCESS AND MOST BENEFICIAL ALL UNITS."

- From CTF SEVENTY SEVEN 151454 OCT 70 (consolidated report from SEVENTHFLT Attack Carrier Strike Force):

" THE WESTPAC MULTICHANNEL BCST REALIGNMENT HAS RESULTED IN IMPROVEMENTS TO BCST SUBSCRIBERS IN THE FOLLOWING AREAS:

A. MANPOWER: SUBSCRIBERS COPY FEWER CHANNELS AND FEWER MSGS PER CHANNEL.

B. RELIABILITY: RERUN CHANNELS ARE AVAIL FOR MSG MISSED ON PRIMARY CHANNELS.

C. MATERIAL: LESS EQUIPMENT AND CONSUMABLE SUPPLIES REQUIRED.

D. SPEED: DELIVERY TIMES ON FIRST RUN TRAFFIC REDUCED."

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*Comment. This is a positive result of simulkeying the single-channel broadcast with a channel of the multichannel broadcast that may have been overlooked.

**Reference (b) of this appendix shows that longer watches and psychological fatigue are factors that greatly degrade our ability to retain experienced radiomen. Thus, these effects may produce even longer-range benefits.

REFERENCES

(a) ComSeventhFlt 290426Z Sep 1970

(b) CinCPacFlt Analysis Staff Study 6-70, "A Survey of Pacific Fleet Communication Personnel and Retention Problems," Unclassified 1 Dec 1970

APPENDIX B

DATA SUMMARIES

TABLE B-1

DATA BASE FOR EVALUATION OF PHASE I
(Implementation of automatic reruns)

	Before (1-14 Sep 1969)				After (6 Oct – 1 Nov 1969)			
	PALD/RTT	PUSN	PNSC	Combined	PALD/RTT	PUSN	PNSC	Combined
Number first-run messages broadcast	7,165	6,144	3,218	16,527	15,279	11,832	6,750	33,861
Average number first-run per day	511.8	438.9	229.9	1180.5	565.9	438.2	250.0	1254.1
Message units/message (average number subscribers)	65.2	50.2	14.1	49.7	86.8	48.9	12.3	58.7
Total message units	467,038	308,712	45,315	821,065	1,326,736	578,703	83,021	1,988,460
Number of service requests	9,029	7,435	1,665	18,129	13,014	5,950	2,285	21,249
Average number requests per day	644.9	531.1	118.9	1294.9	542.3	247.9	95.2	885.4
Service request rate	.019	.024	.037	.022	.010	.010	.028	.011
Service requests per 1000 first-run	1260.2	1210.1	517.4	1096.9	851.8	502.9	338.5	627.5

TABLE B-2

DATA BASE FOR EVALUATION OF PHASE II
(Removal of terminated units from channels 1-4)

Sample period: March 1970

	PALD/RTT	PUSN	PNSC	Combined
Number first-run messages broadcast	14,785	7,188	6,884	28,857
Average number first-run per day	616.0	299.5	286.8	1202.4
Message units/message (average number subscribers)	74.7	45.7	13.3	52.8
Total message units	1,104,723	328,314	91,365	1,524,402
Number service requests	9,797	3,349	2,984	16,130
Average number requests per day	445.3	152.3	135.6	733.5
Service request rate	.009	.010	.033	.011
Service requests per 1000 first-run	662.6	465.9	433.5	559.0

TABLE B-3

DATA BASE FOR EVALUATION OF PHASE III
(Assignment of channels 1-4 by ship type)

	Before (1-18 Aug 1970)				After (19 Aug – 2 Sep 1970)			
	PALD/RTT	PUSN	PNSC	Combined	PALD/RTT	PASW	PNSC	Combined
Number first-run messages broadcast	8,308	4,421	4,553	17,282	7,873	5,984	2,272	16,129
Average number first-run per day	553.9	294.7	303.5	1152.1	524.9	398.9	151.5	1075.3
Message units/message (average number subscribers)	69.9	48.1	13.8	49.5	34.8	20.2	18.2	27.1
Total message units	580,544	212,801	62,964	856,309	273,949	120,847	41,430	436,226
Number of service requests	5,743	4,042	4,302	14,097	1,749	1,396	2,218	5,363
Average number requests per day	383.5	269.5	286.8	939.8	116.6	93.1	147.9	357.5
Service request rate	.010	.019	.068	.017	.006	.012	.054	.012
Service request per 1000 first-run	692.5	914.3	944.9	815.7	222.2	233.3	976.2	332.5

TABLE B-4

DATA FOR CALCULATING DEMAND REPRESENTED BY A FIRST-RUN MESSAGE

Channel	1-14 Sep 1969			5 Oct -- 1 Nov 1969			1-31 Mar 1970		
	Number first-run	Number ZDK's	Demand	Number first-run	Number ZDK's	Demand	Number first-run	Number ZDK's	Demand
PALD/RTT	7907	577	1.073	17164	1013	1.059	20067	975	1.049
PUSN	6779	566	1.083	13688	387	1.028	10622	379	1.036
Both combined	14686	1143	1.078	30852	1400	1.045	30689	1354	1.044
PNSC	3274	104	1.032	8371	359	1.043	9685	96	1.010

Channel	1-18 Aug 1970			19 Aug – Sep 1970		
	Number first-run	Number ZDK's	Demand	Number first-run	Number ZDK's	Demand
PALD/RTT	9940	419	1.042	7611	129	1.017
PASW	5257	230	1.044	6019	244	1.041
Both combined	15197	649	1.043	13630	373	1.027
PNSC	5191	82	1.016	2104	1	1.000

TABLE B-5

VALUES USED IN ESTIMATING THE CHANGE IN BROADCAST WORKLOADS

A. Proportion of the total first-run volume carried by each channel (V_i)

PALD/RTT	PUSN	PNSC
0.451	0.349	0.199

B. Proportation of traffic that would have been rerouted under the realignment (T_{ij}):

That would have gone on:	Traffic appearing on:		
	PALD/RTT	PUSN	PNSC
PALD/RTT	0.636	0.498	0.0
PUSN	0.496	0.499	0.0
PNSC	0.185	0.307	1.0

APPENDIX C

DERIVATION OF CHANGE IN CAPACITY FROM CHANGE IN DEMAND

In the text, the demand represented by a first-run message is represented by an expression of the form

$$D = 1 + m, \tag{C-1}$$

where m is the ratio of ZDK messages to first-run messages. To translate this demand measure for two different periods to an estimate of the change in potential capacity, suppose that the demand for periods 1 and 2 are known and given by

$$D_1 = 1 + m_1 \text{ and } D_2 = 1 + m_2 \tag{C-2}$$

respectively, and let N = total channel capacity measured as the number of messages it can carry during a fixed time period. Then if F is the number of first-run messages that can be transmitted during that period,

$$N = F(1+m) \text{ or } F = \frac{N}{1+m}, \tag{C-3}$$

since each first-run message is assumed to generate m ZDK messages which must also be transmitted. Then, for the two different periods under consideration, the difference in the number of first-run messages that can be transmitted is simply

$$F_2 - F_1 = \frac{N}{1+m_2} - \frac{N}{1+m_1}, \tag{C-4}$$

and the proportional change in first-run capacity in going from period 1 to period 2 is given by

$$\frac{F_2 - F_1}{F_1} = \left[\frac{N}{1+m_2} - \frac{N}{1+m_1}\right]\frac{(1+m_1)}{N}, \tag{C-5}$$

which, upon simplification becomes,

$$\frac{F_1 - F_2}{F_1} = \frac{(1+m_1) - (1+m_2)}{(1+m_2)}, \tag{C-6}$$

independent of N (and therefore independent of the length of the periods considered). The expression shown in equation (6) of the text is derived immediately by identifying $1+m_1$ as the demand before and $1+m_2$ as the demand after, and converting the proportion in equation (C-6) to a percentage.